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E75-10015

ERTS PROGRESS REPORT

FOR THE PERIOD 1 AUGUST TO 30 SEPTEMBER, 1974

TMX-72076

PLANNING APPLICATIONS IN EAST CENTRAL FLORIDA

PROPOSAL NO. Y-10-066-001

BREVARD COUNTY PLANNING DEPARTMENT

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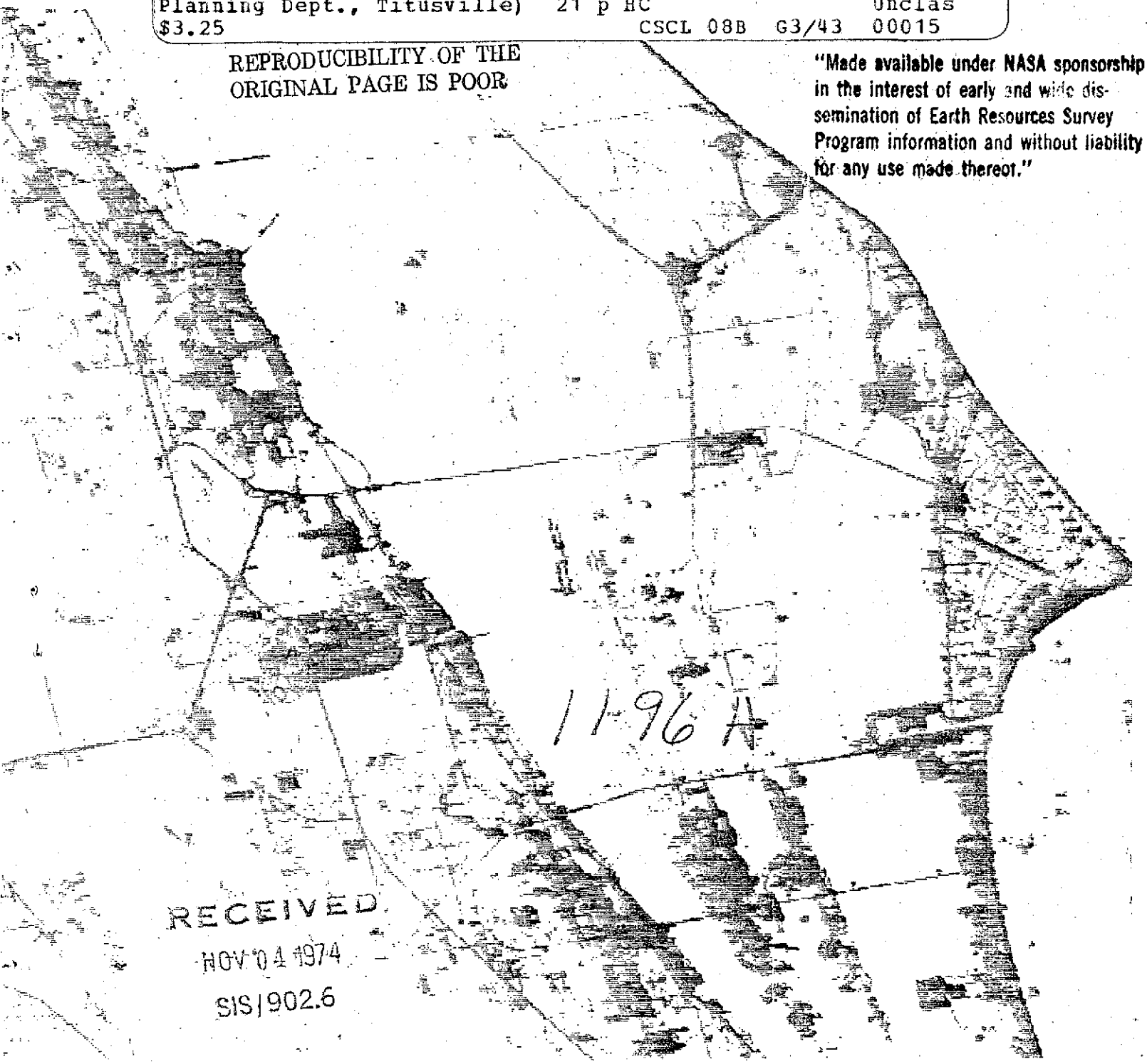

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ERTS PROGRESS REPORT

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PLANNING APPLICATIONS IN EAST CENTRAL FLORIDA

PROPOSAL NO. Y-10-066-001

Principal Investigator: John W. Hannah*

Co-Investigators: Dr. Garland L. Thomas*
Fernando Esparza**

Computer Programming: James J. Millard**

* Brevard County Planning Department

** NASA, Kennedy Space Center

COMPUTER PROGRAMS

A maximum likelihood classification capability has now been developed and put into operation. The flow scheme for this program was developed by Fernando Esparza, in consultation with G. L. Thomas, and the programming was done by James J. Millard.

Three programs have been written.

(1) Classification Program.

The principal feature of this program is the maximum likelihood classification procedure, which is based on the mathematical method outlined by Swain. [1] Since this method is rather costly in terms of computer time, two other alternatives were added to provide perhaps less exact results at reduced computer time. They are: (a) classification according to the class which has its centroid the least Euclidean distance from the point being classified, and (b) choosing the three nearest classes by the above distance measurement and then using the maximum likelihood method to make the classification from among those three classes. For purposes of discussion, we shall refer to these three options as MAXLIK, MINDIST, and MAX/MIN, respectively.

After any one of the above analysis methods is concluded for each data sample, the appropriate class character is assigned for mapping purposes. Concurrently, a character count for each class determined is maintained for tabulation and use during analysis of the requested rectangular area under investigation. Up to eight classes may be requested to describe any area.

[1] Philip N. Swain. Pattern Recognition: A Basis for Remote Sensing Data Analysis.
LARS Information Note 111572 (9/10/73)

(2) Matrix Tape File Generation Program

This program computes the necessary parameters needed for the maximum likelihood technique from training data samples of various land-use classes as observed in the four MSS bands. The parameters include the covariance matrix for each class and the respective matrix determinant and centroid values of each band for each class established. The parameters then are recorded on a magnetic tape for use in the other programs described. Different files have been created for various areas under investigation as well as for each ERTS data set used due to differing radiance values caused by differing atmospheric conditions and sun angles.

(3) Character Counting Program

This program yields the character count and fraction of the total for each class with the added capability to examine any polygonal shaped area, not feasible in the Maximum Likelihood program. The logic within the Maximum Likelihood program is applicable, except for omission of mapping output.

It is appropriate at this point to acknowledge the contributions of Jay Millard. In addition to doing the bulk of the computer programming, as indicated by the title page, he also has handled the input parameters for the various computer runs as requested by the co-investigator, and has made numerous innovations to the programs and participated in the interpretation of results.

COMPUTER TIME REQUIREMENTS

The time-saving value of the two alternate methods is indicated by the following figures on central processor time on the G. E. 635 computer for six-class maps of the Titusville area (72,240 pixels, 129 mi. ^{2}).

METHOD	TIME
MAXLIK	16.9 Min.
MAX/MIN	12.6
MINDIST	5.8

ACCURACY OF RESULTS

As indicated above, the program computes the fraction of the total area represented by each class being considered. When these results are compared for the three alternatives, some differences are found, as indicated by the figures of Table 1. Those figures apply to the total region shown in the MAXLIK map of Figure 1. Study of Table 1 shows that the minimum distance method, compared to the maximum likelihood method shows significantly reduced residential area and slightly increased water, marsh, and undeveloped areas. In an attempt to understand the differences, plots have been made of the histograms and centroid locations for the training samples of the six classes and are given in Figures 2 to 6. Some basis for the higher number of residential choices made by the maximum likelihood method can be seen in the wider spread of the residential histograms as compared to the histograms for the water, marsh, and undeveloped classes. Of course, it needs to be kept in mind that the training samples were carefully chosen and a test points does not necessarily fit neatly into a classification. An example of this is a sector which was classified as undeveloped by the minimum distance method and as residential by the maximum likelihood method. The sector actually is undeveloped with relatively sparse vegetation so that some sand shows through.

In an attempt to evaluate the accuracy of the three classification methods, a check was made of individual characters (pixels) by simple random sampling using a random number table to choose the line and sample number for samples within the solid lines of Figure 1. Aerial photography (color infrared

TABLE I

CLASS	CHARACTER REPRESENTATION	FRACTION OF TOTAL		
		MAX LIK	MAX/MIN	MIN DIST
water	blank	34%	34%	37%
undeveloped	·	26%	25%	28%
marsh	S	20%	22%	22%
residential	/	18%	17%	10%
commercial	X	1%	1%	2%
industrial new construction bare sand	B	2%	1%	00

FOLDOUT FRAME

FOLDOUT FRAME

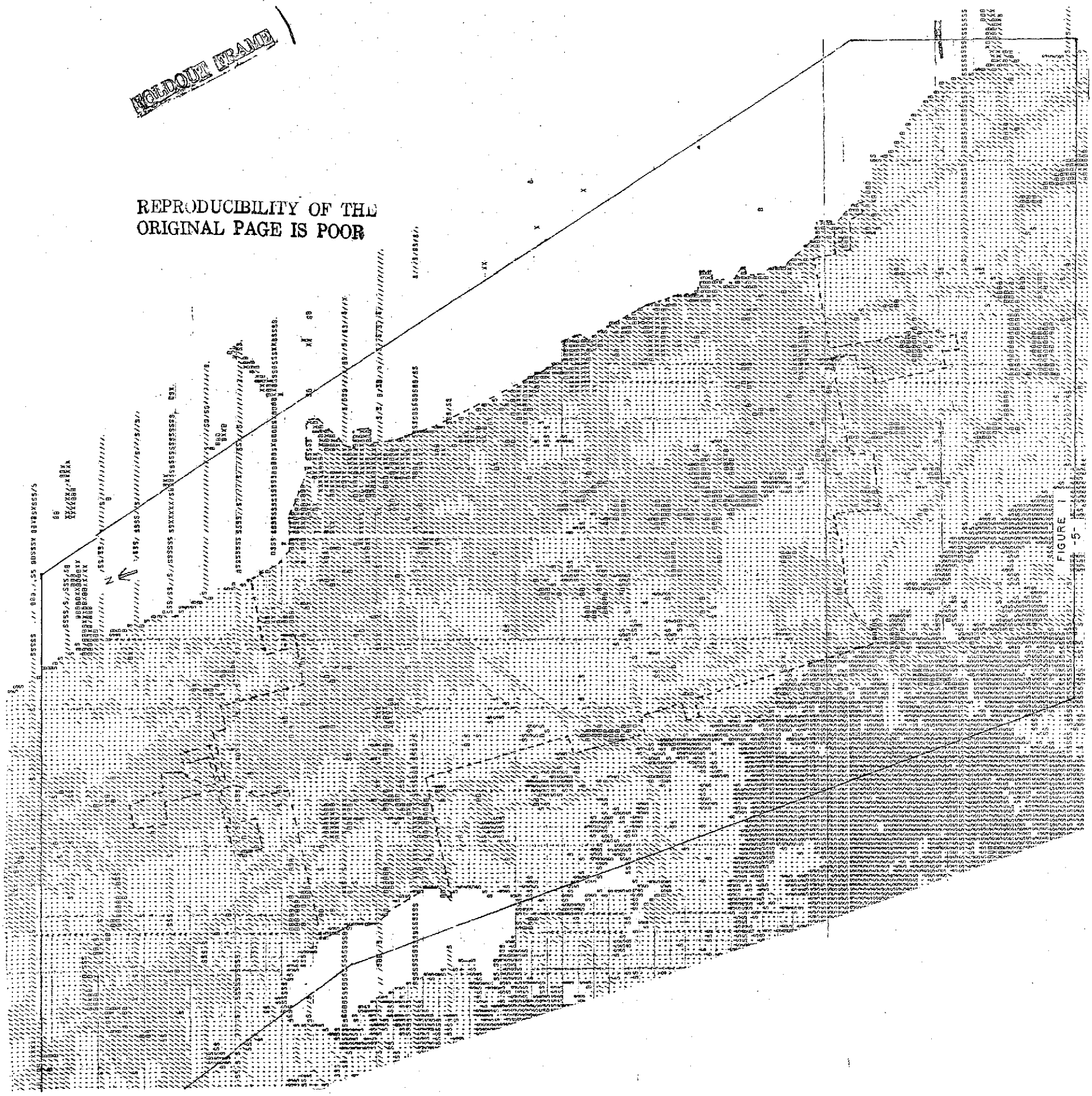

FIGURE 1 -5-

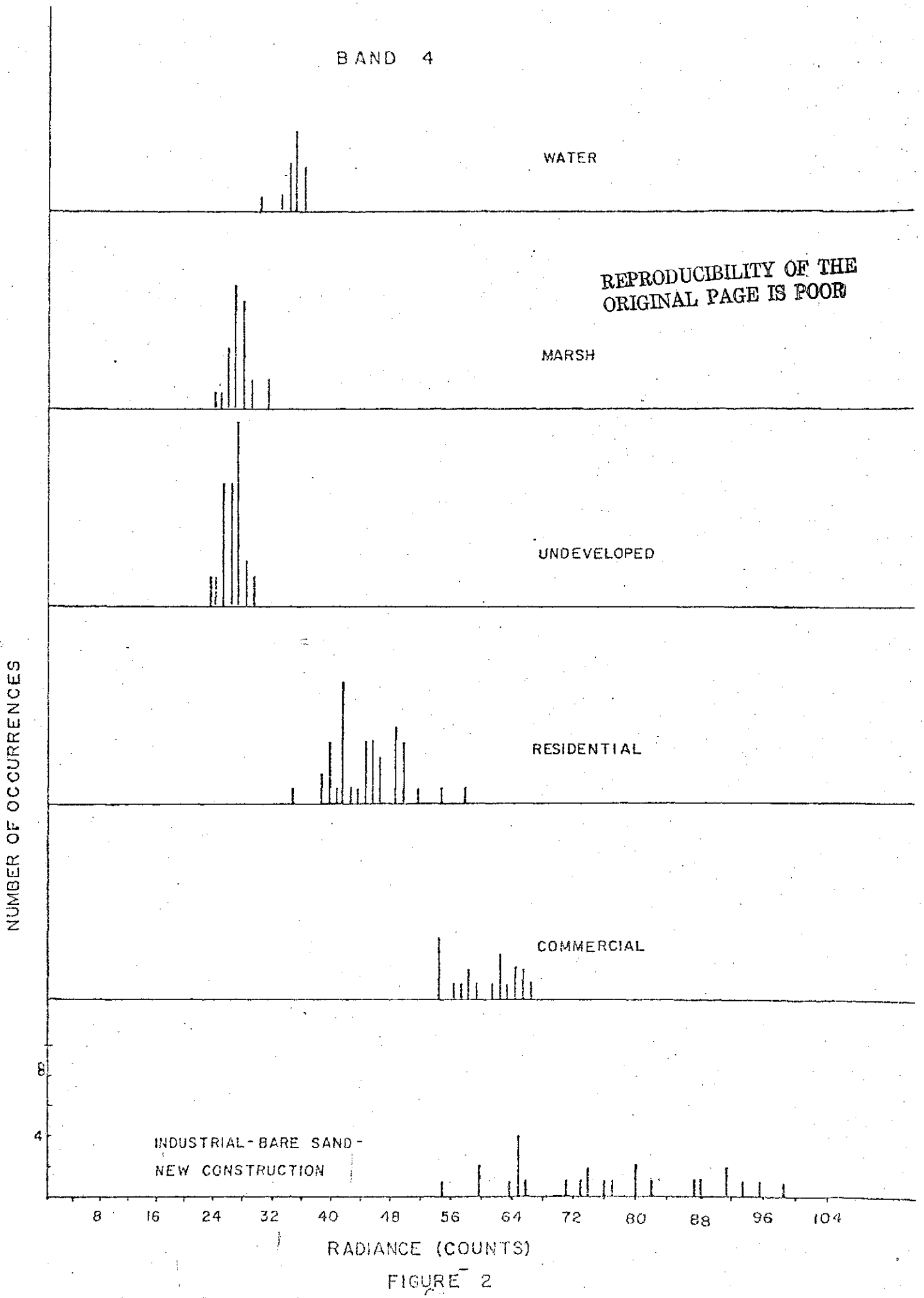

FIGURE 2

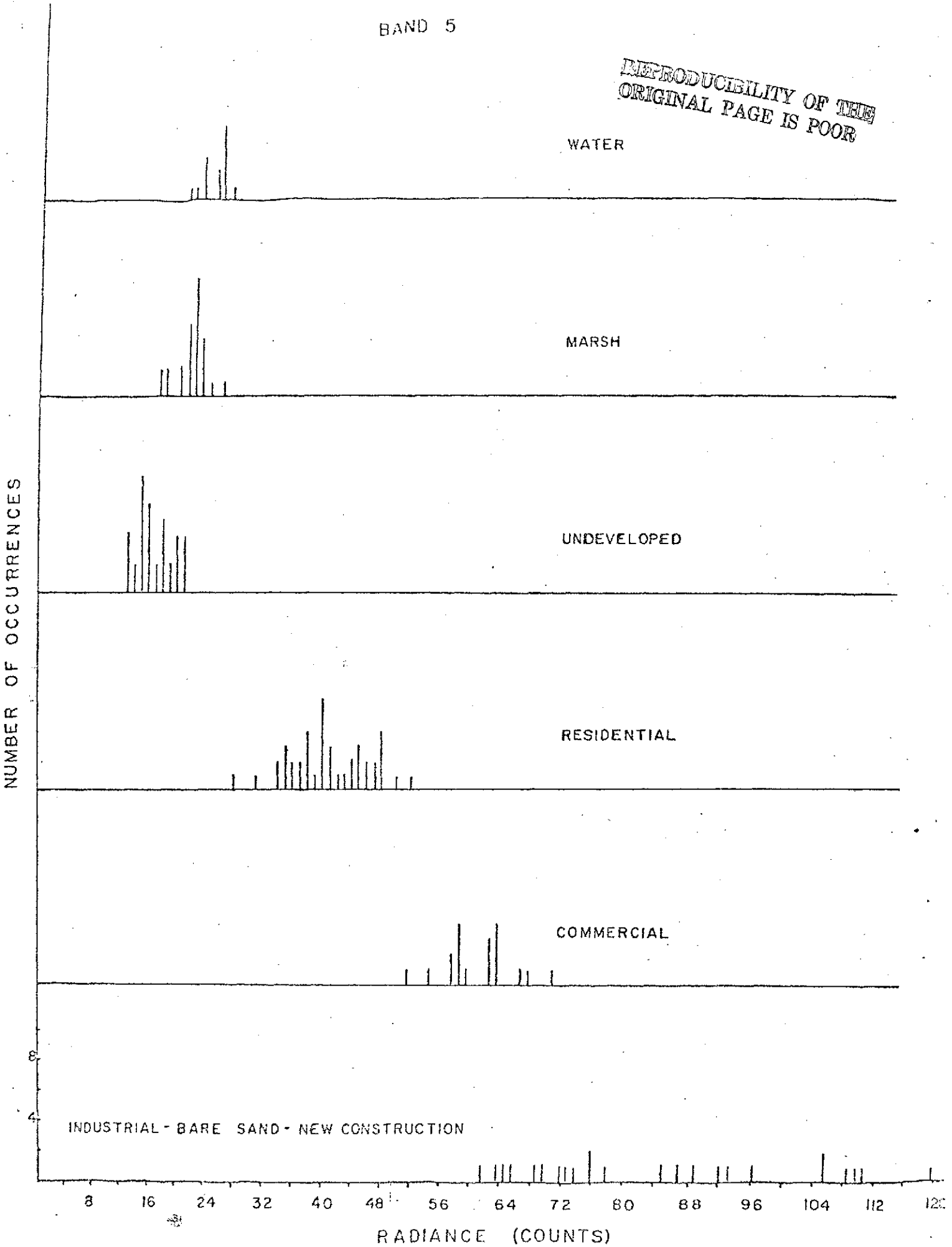

FIGURE 3

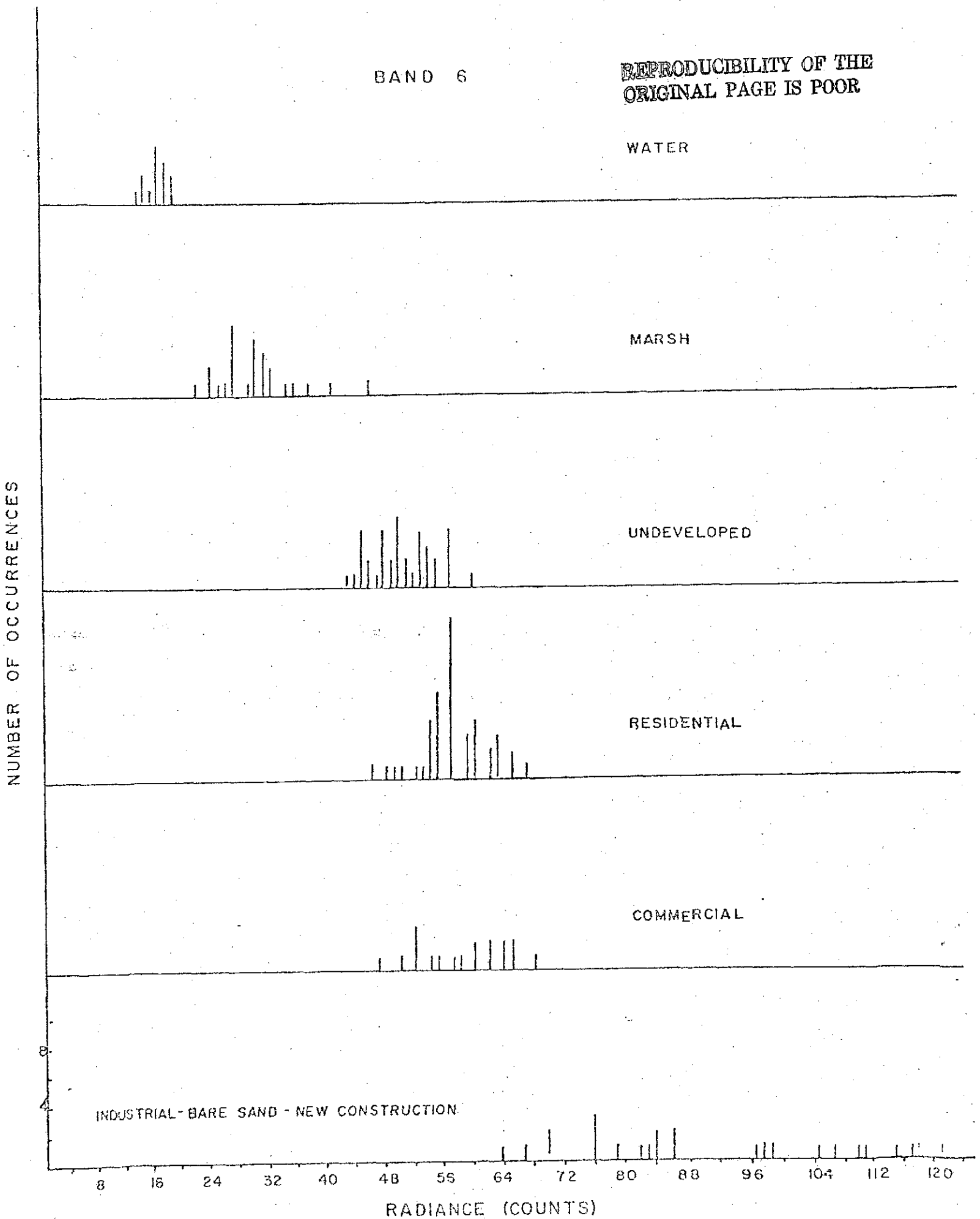

FIGURE 4

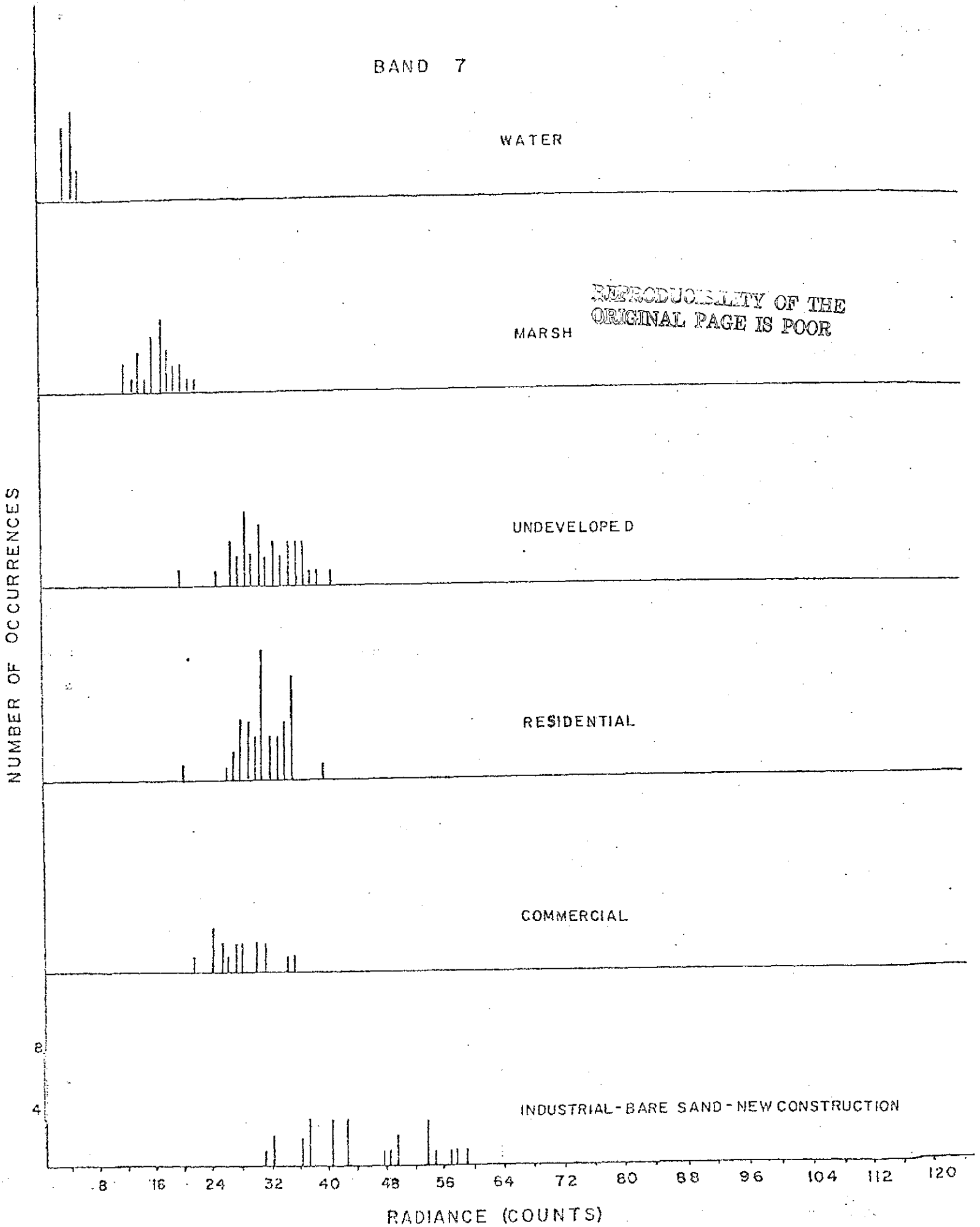

FIGURE 5

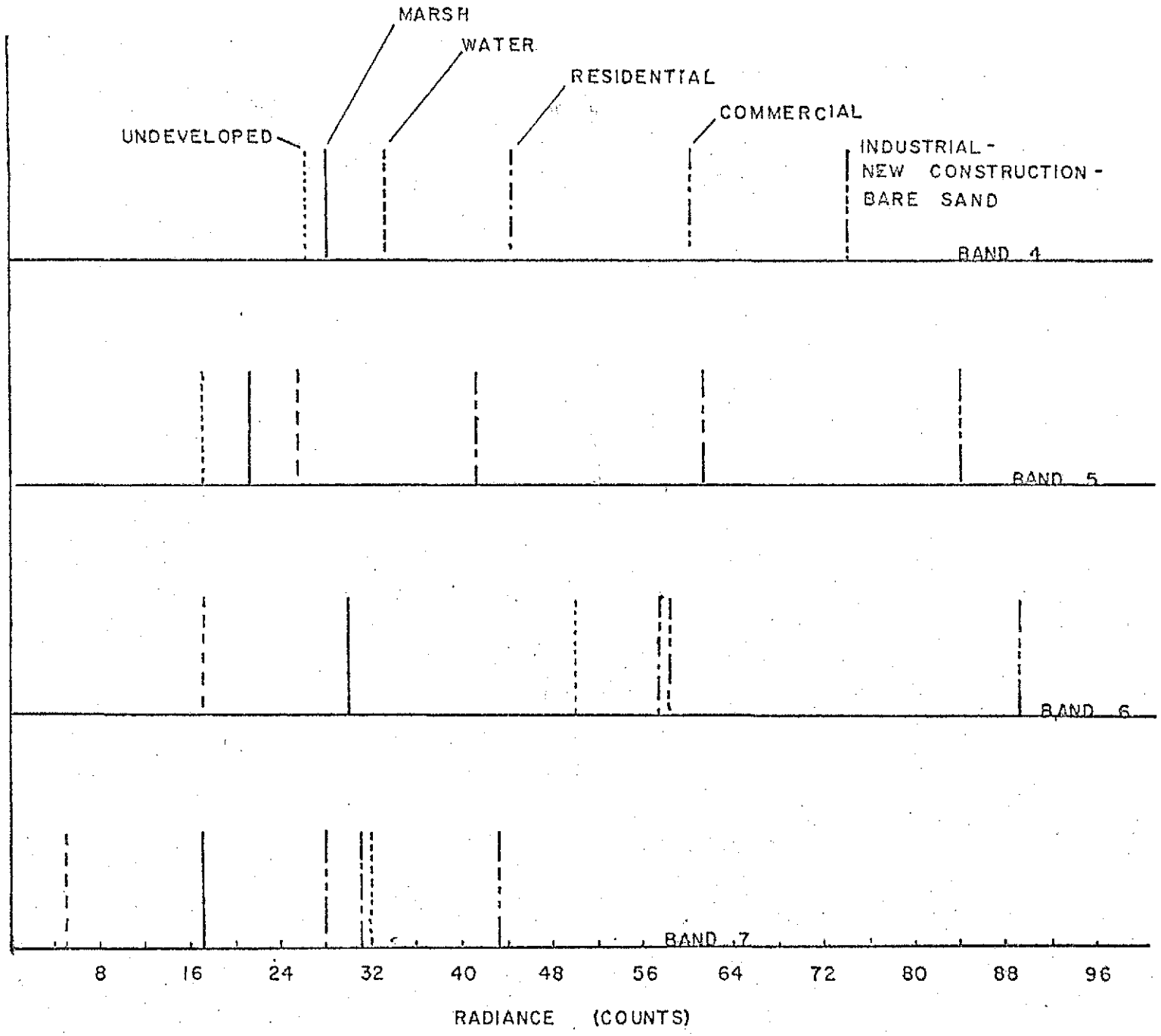
MARSH
WATER
RESIDENTIAL
COMMERCIAL
UNDEVELOPED
INDUSTRIAL -
NEW CONSTRUCTION -
BARE SAND
BAND 4
BAND 5
BAND 6
BAND 7
8
16
24
32
40
48
56
64
72
80
88
96
RADIANCE (COUNTS)

FIGURE 6

and panchromatic) was the primary source of ground truth information, reinforced by local knowledge and the Titusville City Planner's land use map. One percent of the total number of points was checked. The results are given in Table 2. The overall accuracy figures can be changed appreciably by the choice of boundaries - in this case by the amount of marsh and open water included within the boundaries - but the relative accuracies of the three methods are not changed. If the "safe" classes of open water and marsh are excluded, the accuracy figures for the three methods become 90, 87, and 89 percent, respectively.

In the sampling results, 56 points were not counted as either correct or incorrect because of the difficulty of making a clear-cut decision. Most of these uncertainties were due to geometric uncertainties at class boundaries; others applied to locations which were mixtures of two classes. Points in this uncounted group included:

Golf courses usually were classified as residential.

One high density residential (apartment) point was classified as commercial.

Major highways were usually classed as residential.

Five points were identified as marsh by MINDIST and as undeveloped by MAXLIK and MAX/MIN. The states of those points at the time of the ERTS pass is not known.

Schools and school yards were usually classed as residential.

How each uncertain points are counted and how much "safe" area is included in the area under consideration have important effects on accuracy figures. For these reasons and since the results quoted here apply to only one region and the number of training samples is small (18 to 42 per class), the accuracy figures should be regarded only as rough indicators.

TABLE 2

CLASS	MAX LIK			MAX/MIN			MINDIST		
	Number Correct	Number Incorrect	% Correct	Number Correct	Number Incorrect	% Correct	Number Correct	Number Incorrect	% Correct
Water	40	0	100%	40	0	100%	40	0	100%
Marsh	31	0	100	29	0	100	29	0	100
Undeveloped	81	8	88	83	11	88	90	4	96
Residential	29	1	97	30	0	100	25	4	86
Commercial	1	1	50	1	1	50	2	0	100
Industrial - new construction - bare sand	7	0	100	2	5	29	1	4	20
OVERALL	189	13	94	185	17	92	187	14	93

A few other points are worth noting:

Urban classes can be expected to be less homogeneous than, say, agricultural classes and, therefore, be more difficult to classify accurately.

Citrus varies widely in spectral pattern due, at least in part, to variations in the amount of sand seen between the trees. In these maps, citrus was sometimes classed as residential.

Separation of commercial and industrial is, in this case, not reliable. Reliable results are obtained if they are combined into a single class.

Some of the B's shown on Figure 1 are bare sand in fairly new residential areas with sparse vegetation. Some others represent areas denuded of vegetation by motorbikes.

At this time we are not able to separate industrial, new construction, and bare sand. The spread of the histogram for this single class is large. Perhaps additional training data will help.

TITUSVILLE

The city limits of Titusville are shown as the dashed line on Figure 1. A character count for the City of Titusville, uncorrected for bad scan lines, gives the results shown in Table 3, along with data prepared by conventional methods by the Titusville Planning Department.

The total areas for the City are in good agreement, indicating that character-counting is a suitable method of determining areas.

The ERTS map, since it is based on physical characteristics, provides some information not normally available on planners' conventional land-use maps: water and marsh areas, in this case. Table 2 indicates that the figures for marsh area are quite reliable; and the figures for water normally are quite reliable, but in this case there is some uncertainty due to the uncertainty in the fit of the city boundary to the river shore line.

On the other hand, the conventional land-use map, based on economic, political and social factors, provides some classifications which an ERTS map cannot provide, e.g., utilities, public, and institutional uses. Thus, a complete correspondence between the two sets of figures is not possible. Some classes can be grouped for comparison, as shown in Table 3.

The residential area on the ERTS map includes essentially everything in the residential area: residences, streets, vacant lots, golf courses, schools, and other features with similar spectral characteristics and, therefore, must be compared with item 7 from the planners' figures. The planners' residential figure applies only to lots containing residences.

As pointed out above, the ERTS map does not give reliable separation between commercial and industrial classes; hence, for comparison purposes, those two classes are combined into a single class. This figure is approximately twice the planners' figures. This difference can be explained on a basis of recording regions which are not commercial or industrial but nevertheless have high light reflectance, e.g., apartment houses, apartment house parking lots, and regions with barren vegetation. B's on the computer map which were believed to be due to bare sand were subtracted from the character count to give the industrial figures quoted. This says that Titusville has 234 acres of bare sand of which 86 acres are denuded of vegetation by motorbike usage.

For the same reasons that the ERTS residential figure is higher than the corresponding planners' figure, the ERTS area for (water and marsh and undeveloped) is lower.

A 1973 conventional land-use map of Titusville is included as Figure 7, for comparison with Figure 1.

TABLE 3

	CLASS	TITUSVILLE PLANNING DEPARTMENT AREA ACRES	AREA HECTARES	% OF TOTAL	ERTS MAP AREA ACRES	AREA HECTARES	% OF TOTAL	PER-CENT DIFFERENCE
(1)	Water				34	14	0	
(2)	Marsh				300	120	3	
(3)	Undeveloped				3573	1429	33	
(4)	Residential	2222	888	21	5744	2298	53	
(5)	Commercial	329	131	3	424	170	4	+29
(6)	Industrial	68	27	1	467	187	4	+587
(7)	Residential, Streets, Rights-of-Way, Utilities Transportation, Public, Institutional	4611	1844	43	(5744)	2298		+25
(8)	Commercial and Industrial	397	159	4	891	356	8	+124
(9)	Water, Marsh and Undeveloped	5730	2292	53	3907	1563	36	-32
(10)	Residential and Highway				5809	2324	54	
(11)	Bare Sand				234	94	2	
	Total	10,738	4295		10,841	4336		+1

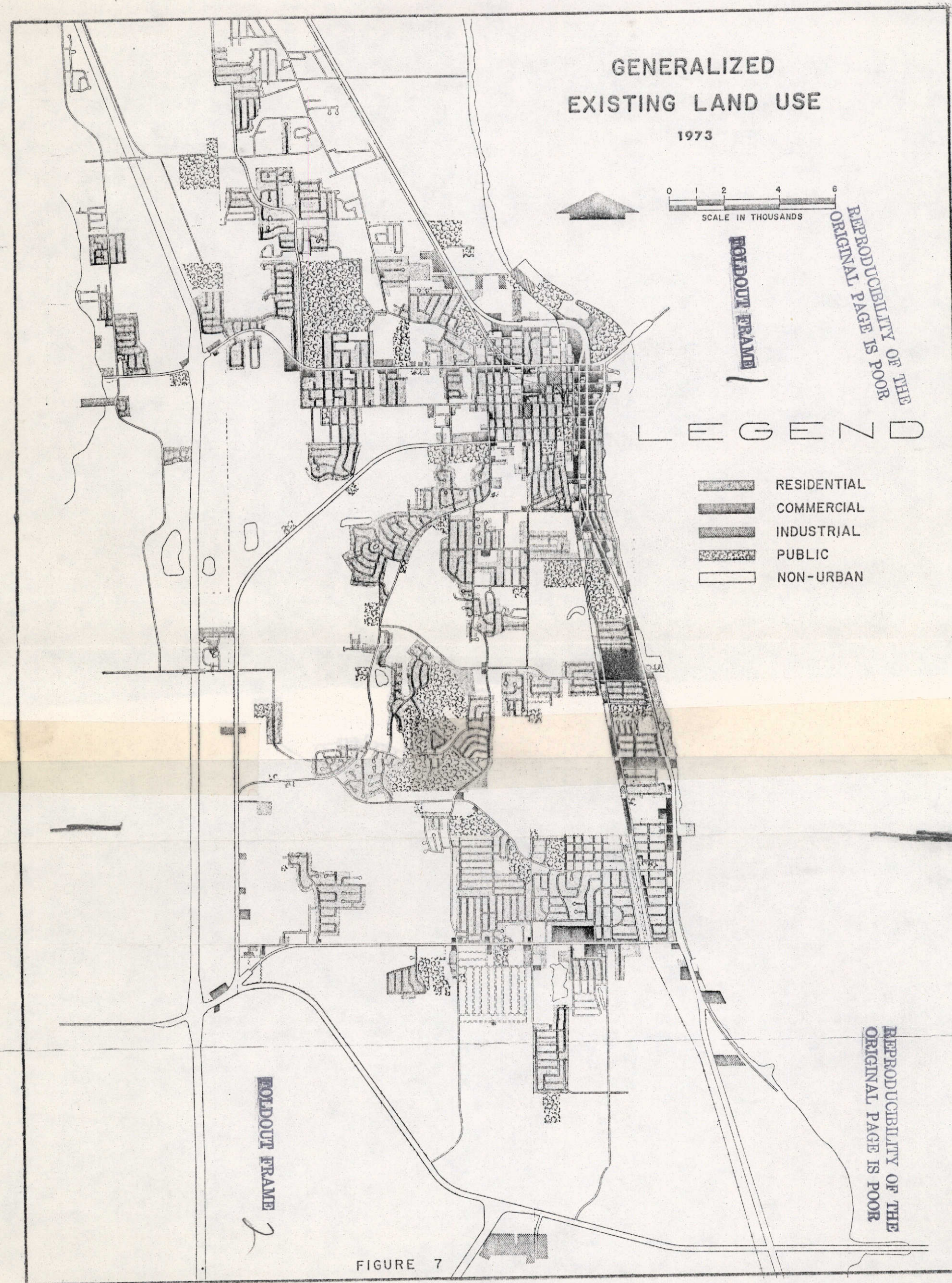
GENERALIZED
EXISTING LAND USE
1973
0 1 2 4 6
SCALE IN THOUSANDS
FOLDOUT FRAME 1
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR
LEGEND
RESIDENTIAL
COMMERCIAL
INDUSTRIAL
PUBLIC
NON-URBAN
FOLDOUT FRAME 2
REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

FIGURE 7